Testimony of

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"One Hand Clapping"

Before the United States House of Representatives
Committee on Government Reform

"Climate Change Technology Research: Do we need a 'Manhattan Project' for the Environment?"

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You have heard a very strong case for moving forcefully forward with technological responses that address climate change. I am in complete agreement with the case for urgency. I will use my few minutes with you to emphasize the need for a full-court press: We need early deployment of technologies that we already know are matched to the job, and we need long-term research to expand the list of options.

Congressional action is critical in both areas.

> To accelerate the deployment of the technological strategies whose promise is already clearly identified requires price signals for carbon. By expanding the cap and trade model to carbon dioxide and adopting specific policies tailored to individual sectors, one can create a market incentive to use today's lower-emitting technologies
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> To raise the energy R&D effort to a new level requires greatly expanded, durable funding of research with a long time horizon. New legislation can create a durable program that insulates researchers from fickle changes in research direction and from pressures to respond to very short term objectives.

Technology-forcing price signals for carbon to promote available technologies and expanded support for R&D go hand in hand. Literally. To do one without the other: that's like one hand clapping.

For the past several years, I have worked to strip down the presentation of the CO_2 and climate problem, so that policy discussions can become more coherent. With my ecologist colleague, Stephen Pacala, I wrote an article in *Science* in 2004 and a second article in this month's *Scientific American*, that made two simple contributions. First, we introduced the "stabilization wedge" as a new unit of measure for quantifying climate mitigation strategies, focusing on the next 50 years. Second, we introduced the "stabilization triangle" as our estimate of the size of the job. A stabilization wedge is a strategy that produces a reduction of 1 billon tons of carbon in global CO_2 emissions fifty years from now, relative to what would happen in the absence of attention to the climate problem. (Ramping up to 800 one-thousand megawatt coal plants equipped with CO_2 capture and storage technology by 2056 is an example of a wedge.) The size of the world's job is seven wedges – under specific assumptions about the world's emissions if there is no attention to carbon and about the highest level of CO_2 in the atmosphere judged to be tolerable. See Figure 1.

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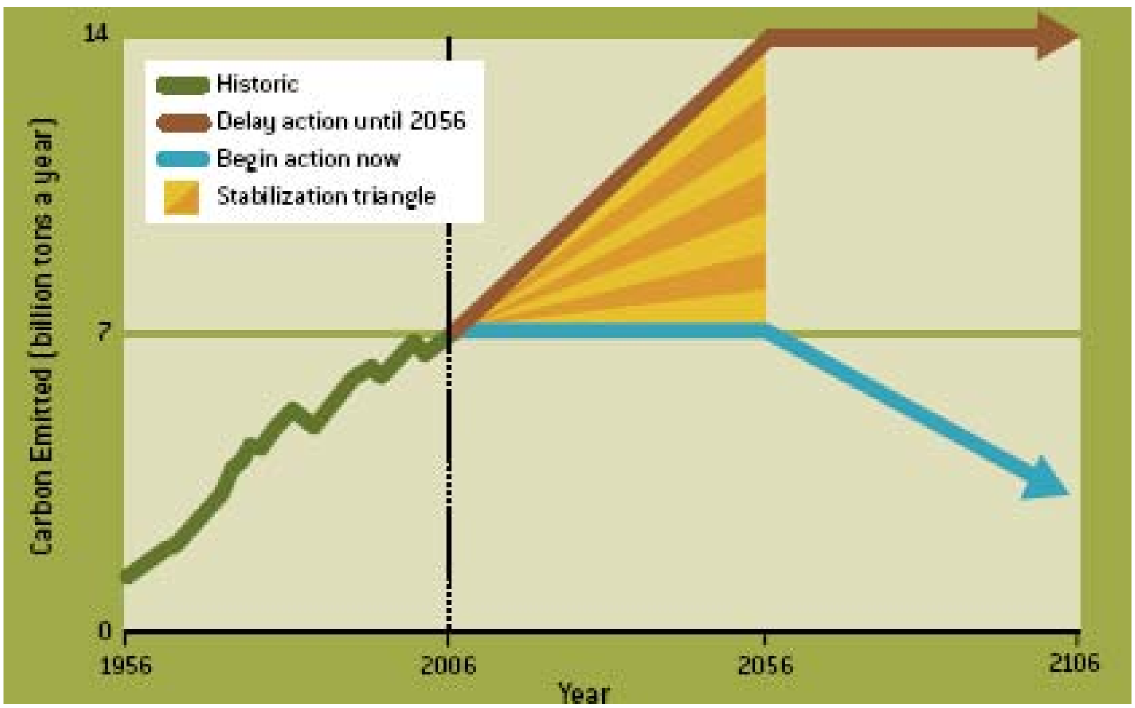

Figure 1. Two trajectories for future global carbon emissions to the atmosphere (as carbon dioxide). The upper trajectory envisions fifty years of inaction, while CO_2 emissions double, followed by aggressive action to hold global emissions constant for the following 50 years. The lower trajectory envisions immediate action to hold global emissions constant, followed in half a century by a second aggressive program to reduce global emissions roughly in half, down to a level where remaining emissions are canceled by absorption of CO_2 by the ocean and land, so that the global atmospheric CO_2 concentration stabilizes. Following the upper trajectory, the world will find it difficult to avoid tripling the pre-industrial CO_2 concentration and a rise in the average surface temperature of roughly 5^{o}C. Following the lower trajectory will enable the world to "beat doubling," that is, to keep the concentration below twice its pre-industrial concentration, with a rise in average surface temperature of roughly 3^{o}C.

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Our diagram is now widely known. The principal criticism we have received over the past two years is that it underestimates the size of the job. Some people think the world's CO_2 emissions will more than double in the next 50 years in the absence of deliberate attention to the climate problem. Others think that the world's goal should be to beat doubling by a large amount, not to cut it close, thereby aiming for a 2^oC, rather than a 3^oC, rise in global surface temperature. Global emissions fifty years from now, in that case, would need to be about half of today's. In short, our critics are urging us to assert that the world will need to achieve *at least* seven wedges.

Pacala and I learned, through our wedge analysis that there is an abundance of promising options, even when we restrict the list to options that involve the scaling up of technologies that have already been commercialized somewhere in the world. In our articles, we listed 15 options and noted that our list was incomplete. The huge size of the mitigation assignment convinced our readers that no option could do the whole job, or even half the job, so that solutions to the climate problem require portfolios of technological strategies. Through a process of international coordination, countries can choose their own portfolios.

A world that emits no more CO_2 in fifty years than today will require that the U.S. emit less CO_2 in fifty years than today. Thus, the solution to the CO_2 problem has three phases:

1. Constant U.S. emissions
2. Constant global emissions
3. Constant atmospheric concentration.

To achieve the CO_2 targets widely advocated by earth-system scientists, including Marty Hoffert here today, will require a trajectory for U.S. emissions that departs from its expected (Business As Usual) trajectory essentially immediately, and peaks in about a decade. Global emissions would peak within two or three decades. These are big assignments. Accordingly, it is critical not to underestimate the size of the policy intervention that will be required to motivate deep changes in the energy system. We could lose much precious time if, after so many years of delay, we implement carbon policy that establishes such a low price for CO_2 emissions that production and consumption patterns hardly change, and industries and consumers simply treat these expenses as routine costs of business.

The criterion for the necessary size of the policy intervention is: Will the price schedule for CO_2 emissions induce fundamental changes in the energy system beginning within a decade or less. Experts in industry economics will be able to guess the right level, and an iterative process should be built in. In our *Scientific American* article, we gave our own estimate of the cost of CO_2 emissions required to produce dramatic changes in the world's forthcoming investments in the energy system:

> "We estimate that the price needed to jump-start this transition is in the ballpark of \$100 to \$200 per ton of carbon— the range that would make it cheaper for

> owners of coal plants to capture and store CO2 rather than vent it. The price might fall as technologies climb the learning curve. A carbon emissions price of $100 per ton is comparable to the current U.S. production credit for new renewable and nuclear energy relative to coal, and it is about half the current U.S. subsidy of ethanol relative to gasoline. It also was the price of CO_2 emissions in the European Union's emissions trading system for nearly a year, spanning 2005 and 2006. (One ton of carbon is carried in 3.7 tons of carbon dioxide, so this price is also $27 per ton of CO2.) Based on carbon content, $100 per ton of carbon is $12 per barrel of oil and $60 per ton of coal. It is 25 cents per gallon of gasoline and two cents per kilowatt-hour of electricity from coal."

This vision of policy-induced scale-up of existing technology still requires R&D. As Pacala and I wrote in *Scientific American*: "Achieving nearly every one of the wedges requires new science and engineering to squeeze down costs and address the problems that inevitably accompany widespread deployment of new technologies. But holding CO2 emissions in 2056 to their present rate, without choking off economic growth, is a desirable outcome within our grasp."

The meeting today is about still another kind of research, more blue sky, more capable of eliciting a certain kind of scientific creativity that the world must also engage, as part of the full-court press. Both the Manhattan Project and the Apollo Program are apt metaphors for programs that captured the imagination and the loyalty of the world's best scientists and engineers. Both programs provided dependable research support, which is a necessary conditions to induce the most productive scientists and engineers to reorient their research careers and to induce the most ambitious students to adopt these retooling scientists and engineers as their mentors. But both models miss two crucial aspects of the job ahead: It must be international, and it must heavily involve the private sector.

Pacala and I concluded our *Scientific American* article by placing ourselves in 2056 and looking back on the 50 years that had just passed. We asked: "If global emissions of CO2 are indeed no larger than today's, what will have been accomplished?"

We answered our own question:

> "The world will have confronted energy production and energy efficiency at the consumer level, in all economic sectors and in economies at all levels of development. Buildings and lights and refrigerators, cars and trucks and planes, will be transformed. Transformed, also, will be the ways we use them. The world will have a fossil-fuel energy system about as large as today's but one that is infused with modern controls and advanced materials and that is almost unrecognizably cleaner. There will be integrated production of power, fuels and heat; greatly reduced air and water pollution; and extensive carbon capture and storage. Alongside the fossil energy system will be a non-fossil energy system approximately as large. Extensive direct and indirect harvesting of renewable energy will have brought about the revitalization of rural areas and the reclamation of degraded lands. If nuclear power is playing a large role, strong

> international enforcement mechanisms will have come into being to control the spread of nuclear technology from energy to weapons. Economic growth will have been maintained; the poor and the rich will both be richer. And our descendants will not be forced to exhaust so much treasure, innovation and energy to ward off rising sea level, heat, hurricanes and drought.
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> "Critically, a planetary consciousness will have grown. Humanity will have learned to address its collective destiny – and to share the planet."

I repeat my main message: We need all possible forms of commitment to combating global warming. The commitments of the basic research community will require a serious expansion of high-risk R&D. But much more is needed. We must create carbon-responsive investments by industry and commitments to carbon-saving practices on the part of consumers. R&D in the absence of technology-forcing policy is like one hand clapping.

Thank you.